

Summer 2015

# The effect of controlled burns on abundance of woody species at Buck Mountain, West Virginia

Barry E. Edgar  
*James Madison University*

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The Effect of Controlled Burns on Abundance of Woody Species at Buck Mountain,  
West Virginia

Barry Elizabeth Edgar

A thesis submitted to the Graduate Faculty of

JAMES MADISON UNIVERSITY

In

Partial Fulfillment of the Requirements

for the degree of

Master of Science

Biology

August 2015

## Acknowledgements

I would like to thank my advisor Dr. Heather Griscom for her guidance and inspiration to become a forest ecologist. She has greatly influenced my scientific thought process, and has made me a better scientist. I would not have been able to write this thesis without her expertise and thoughtful input. I would also like to thank my committee members Dr. Conley K. McMullen and Dr. Bruce Wiggins for their guidance and constructive feedback.

I would like to acknowledge my field assistants Dakota Kobler, Sarah Maher, Kevin Tomlinson, and Becca Sanders for their hard work. I would not have survived Buck Mountain without them. I would like to thank the U.S. Forest Service, specifically Sami Schinnell, Tom Ledbetter, and Fred Huber for their help and great knowledge of Buck Mountain. Lastly, I would like to thank the James Madison University Biology Department and the Graduate School for funding.

## Table of Contents

Acknowledgements.....	ii
List of Tables....	iv
List of Figures.....	v
Abstract.....	vi
I. Introduction.....	1
II. Methods.....	8
Study Site.....	8
Vegetation Sampling.....	10
Data Analysis.....	10
III. Results.....	11
Effect of fire on the canopy.....	11
Effect of fire on the understory.....	14
Effect of fire on shrub species.....	17
IV. Discussion.....	19
Summary.....	19
Oak regeneration.....	19
Oak competitors.....	20
Desired shrub species.....	21
Future studies and management.....	22
V. References.....	23

## List of Tables

Table 1. Importance values for six most prevalent adult tree species in the no-burn and burn treatments.....	13
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Table 2. Total density and total basal area per ha for selected adult tree species of the burn treatments.....	14
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## List of Figures

Figure 1. Map of study site with burn treatments and vegetation sampling plots on Buck Mountain, West Virginia.....	9
Figure 2. Total basal area per ha for selected adult tree species.....	14
Figure 3. Density for selected tree sapling species.....	16
Figure 4. Density for selected tree seedling species.....	17
Figure 5. Density for selected shrub species.....	18

## Abstract

Each year, the U.S. Forest Service prescribes burns within the George Washington and Jefferson National Forest (GWJNF). Burns are prescribed in the growing (late April-October) and dormant season (November- mid-April). The goal of the burns is to reinstate the natural fire regime, returning forests to their original species composition. Currently in GWJNF, Appalachian pine-oak forests are experiencing an increase in fire-intolerant species, while *Quercus* species and *Gaylussacia brachycera*, an endangered shrub species, are declining. In the summer of 2014, a vegetation survey was conducted on Buck Mountain, West Virginia to determine if there was a significant difference between dormant and growing season burns compared to a no-burn control. A total of 60 plots (15 per treatment) was established within a site burned once (in the dormant season), a site burned twice (dormant burn followed by a growing season burn), a site burned twice (both dormant), and a site protected from fire (control). We hypothesized that burns would have differing effects on woody vegetation, depending on fire treatment and shade tolerance. We predicted that *Quercus* species and *G. brachycera* would increase after a growing season burn. We found that *Quercus ilicifolia* regeneration, as well as *G. brachycera* were more abundant at burn sites, regardless of season. Our results suggest that seasonality of burns did not affect oak and *G. brachycera* regeneration at Buck Mountain. Future vegetation monitoring is needed to determine if time intervals between burns affects regeneration of desired species rather than the season of burn.

## INTRODUCTION

Fire is a natural disturbance regime that greatly influences the vegetation composition and structure of a forest (Lafon *et al.* 2005). Fires create a mix of successional stages, thus increasing plant diversity and forage production for birds and other wildlife. Patterns of fire periodicity, seasonality, intensity, and area determine the natural disturbance regime of a landscape (Lafon *et al.* 2005). Historically, fires caused by lightning strike in the southeastern United States were low in severity, but relatively high in frequency (Santiestevan 2012; Knapp *et al.* 2009). Fires would cycle multiple times a year to once every 35 years in late spring or early summer (Santiestevan 2012; Knapp *et al.* 2009). Traditionally, Native Americans used fire to drive game, improve wildlife habitat, and clear underbrush (Lafon *et al.* 2005). Post-European settlement fires were used to convert forests to farmlands (Huebener 2006). Many slow growing plant species, such as *Quercus* (oak) species relied on natural fire regimes to suppress fast growing, fire intolerant, and competitive species, such as *Acer rubrum* (red maple), and *Liriodendron tulipifera* (tulip poplar).

However, beginning in the 1920s natural fires began to be suppressed in order to protect forested lands (Stephens & Ruth 2005). Suppressing the natural disturbance regime has resulted in altered forest composition (Stephens & Ruth 2005). One such change in composition is in the increase in abundance of *A. rubrum* and other shade tolerant plant species, such as *Kalmia latifolia* (mountain laurel) in the canopy and understory. In order to return the forests to their original species composition, the U.S. Forest Service (USFS) started prescribing dormant season burns in the mid-1990s. In the mid-1990s the main objective of the burns was to reduce fuel loads (Stephens & Ruth



2005). However, federal fire policy has changed greatly since 1995, recognizing fire as an essential ecological process (Stephens & Ruth 2005). Today, in the southeastern U.S., prescribed burns are intended to restore oaks as the dominant species in the canopy, suppressing *A. rubrum*.

Currently, controlled burns are either conducted during the growing (late April-October) or dormant season (November- mid-April) every 3-25 years. Dormant season burns are ideal since they are prescribed before hardwood tree species have leafed out, so leaf litter is exposed to sunlight, creating ideal burning conditions, and the direct impacts to nesting birds is reduced (Knapp *et al.* 2009; Brennan *et al.* 1998; Main & Tanner 1999). For these reasons the majority of burns have been conducted by the USFS in the dormant season. To recover from burns, plants rely on stored carbohydrates to re-sprout and grow (Knapp *et al.* 2009). Plants usually have the lowest levels of carbohydrates in the early growing season due to higher energy expenditure and at this active time plants might recover at a slower rate than if burns were conducted during the dormant season (Knapp *et al.* 2009). However, unlike the majority of plants, certain tree species, such as *Quercus* have large taproots with stored carbohydrates, allowing them to be competitive after growing season burns (Brose *et al.* 1999).

Even with the potential to have a competitive edge, *Quercus* spp. and woody shrubs are declining in in Appalachian pine-oak forests due to an increase in fire-intolerant species. After the Chestnut Blight decimated *Castanea dentata* (American chestnut) in the early 1900s, *Quercus* assumed the role of the foundation species in hardwood forests in the southeastern United States (Alexander *et al.* 2008). Since *Quercus* spp. are large mast producers, many animals depend on oaks for food. *Quercus*

spp. are considered relatively slow growing, mid shade tolerant, and fire resistant (Carey 1992; Cooper *et al.* 1999; Green *et al.* 2010). They are fire resistant due to their hypogeal germination, meaning their root collars and dormant buds are below ground (Brose 2010; Brose *et al.* 1999). *Acer rubrum*, a competitor of oaks, is a shade tolerant and a fire sensitive species (Arthur *et al.* 1998; Green *et al.* 2010; Signell *et al.* 2005). *Acer rubrum* can be prolific seeders, as well as aggressive stump sprouters (Arthur *et al.* 1998). Fire-intolerant species, such as *Acer rubrum*, can out-compete *Quercus* spp. in mesic, dense shade environments (Brose & Van Lear 1998; Elliot & Vose 2010; Holzmüller *et al.* 2009). Unlike *Quercus* spp., *A. rubrum* have epigeal germination, where their root collars and dormant buds are above ground, making the species susceptible to fires (Brose 2010). *Nyssa sylvatica* (black gum), another common tree in Appalachian pine-oak forests is also shade tolerant and has epigeal germination like *A. rubrum* (Burns & Honkala 1990). Despite having epigeal germination, *N. sylvatica* is very fire tolerant due to the species' thick bark and high moisture content in the trunk (Coladonato 1992).

Few controlled burn studies have been conducted in the hardwood stands of southern Appalachia (Knapp *et al.* 2009). The majority of the studies conducted in the southern Appalachian Mountains have looked at pine-hardwood forests, where pines represent 50% of the canopy; these forests only comprise 5% of southern Appalachia (Elliott & Vose 2010). We need to understand the effects of growing and dormant season burns on vegetation, given the interest by the USFS to promote oak regeneration and conflicting recommendations from the literature (Sparks *et al.* 1998; Brose & Waldrop 2014).

Some studies have found growing season burns have less soil erosion due to reduction in soil exposure (Knapp *et al.* 2009; Dobrowolski *et al.* 1987). Repeated growing season burns have also been shown to increase the cover and diversity of herbaceous species due to reduction in shrub competition, benefiting grazing animals (Knapp *et al.* 2009; Hutchinson *et al.* 2005). Species in Ericaceae are beneficial for wildlife foraging; increasing their population size with fire may benefit fauna. Growing season burns have been found to increase percent cover of *Gaylussacia baccata* (black huckleberry) and *Vaccinium* spp. (blueberry species) (Elliot *et al.* 1999), while dormant season burns have been found to decrease these species (Arthur *et al.* 1998). *Gaylussacia brachycera* (box huckleberry), a species of interest, is considered to be imperiled or endangered in the southeastern United States. Reduction in *G. brachycera* populations is due to decrease in forest habitat (DePalma 2014; Felbaum *et al.* 1995). Prescribed burning could be beneficial to *G. brachycera*, a slow growing plant, in reducing fast growing competitors.

Many studies have found *Quercus* seedlings and saplings to be most abundant after a single growing season burn compared to a dormant season burn (Brose 2010; Brose & Van Lear 1998; Brose *et al.* 1999; Elliot *et al.* 1999). However, this may be species specific. Elliot *et al.* (1999) found only *Q. prinus* and *Q. coccinea* saplings benefited from a growing season burn; *Q. alba*, *Q. velutina*, *Q. rubra* saplings did not benefit (Elliot *et al.* 1999).

Growing season burns are more effective in decreasing seedlings and saplings of the oak competitor, *A. rubrum*, while seasonality of burns has not been found to affect *N. sylvatica*, another competitor of *Quercus* spp. (Teuke & Van Lear 1982; Dey & Hartman

2005). Single growing season burns reduced *A. rubrum* saplings (Brose 2010; Brose & Van Lear 1998) and seedlings (Elliot *et al.* 1999; Brose 2010; Brose & Van Lear 1998). Green *et al.* (2010) suggest that burns occurring in the later growing season could potentially reduce *A. rubrum* seedlings, and lower the growth of surviving maples. During the later growing season *A. rubrum* are more physiologically active, thus the additional stress of burning on a seedling could hinder growth (Green *et al.* 2010). The effect of dormant season burns is unclear as research has shown that these burns both promote *A. rubrum* (Arthur *et al.* 1998; Teuke & Van Lear 1982), and reduce *A. rubrum* regeneration (seedlings and saplings) (Alexander *et al.* 2008).

However, Brose and Van Lear (1999) found growing season burns caused more damage to adult trees, including *Quercus* spp., than dormant season burns. The combination of warm temperatures, direct sunlight on trunks, and fully hydrated vascular tissues allowed temperatures within the trunk to reach 140°F, causing cell death (Brose & Van Lear 1999). Dormant season burns cause less damage to overstory trees due to cooler temperatures, low insolation levels, and the dormant state of the trees (Brose & Van Lear 1999).

Seasonality is one variable with controlled burns, but frequency of burns is another. Studies with single dormant season burns have conflicting results regarding oak regeneration. Teuke and Van Lear (1982) found *Quercus* saplings significantly decreased post dormant season burn, where as Dey and Hartman (2005) only found a small reduction in *Quercus* saplings. With regard to seedlings, a single dormant season burn has been found to both increase (Brose & Van Lear 1998; Teuke & Van Lear 1982) and decrease *Quercus* seedlings (Alexander *et al.* 2008; Johnson 1974). In Brose and

Waldrop's (2014) review of the Johnson (1974) study, the authors suggest excessive deer browse and original small seedling sizes could explain the reduction in oak regeneration. Brose and Waldrop (2014) also suggest the timing of the Johnson (1974) study could explain the decrease in seedlings. Prior to the late dormant burn, small seedlings could have expanded leaves, thus increasing seedling mortality post burn (Brose & Waldrop 2014).

Repeated burns have been found to favor *Quercus* seedlings (Fan *et al.* 2012; Dey & Hartman 2005), but not saplings (Arthur *et al.* 2015). Arthur *et al.* (2015) found two burns had the highest density of *Q. prinus* seedlings. Multiple burns favor oak regeneration by reducing competitors of oaks over a single prescribed burn (Dey & Hartman 2005). After 3-4 burns, seedlings may suffer (Green *et al.* 2010). A fire-free period is needed for *Quercus* seedlings and saplings to reach into the overstory (Fan *et al.* 2012).

Repeated burns also decrease seedlings and saplings of the oak competitor, *N. sylvatica* (Arthur *et al.* 1998; Dey & Hartman 2005; Fan *et al.* 2012), and *A. rubrum* (Arthur *et al.* 1998; Arthur *et al.* 2015; Green *et al.* 2010). Repeated burns have reduced *A. rubrum* regeneration. However, Alexander *et al.* (2008) found repeated burns did not reduce *A. rubrum* regeneration greater than a single burn. Burning too frequently or having severe fires may expose mineral beds, which favor smaller seeded species, such as *A. rubrum* (Arthur *et al.* 2015).

Prescribed burns are not only beneficial in decreasing tree competitors of *Quercus* spp., but potentially native shrub species, such as *Kalmia latifolia* (mountain laurel). *Kalmia latifolia* can prolifically sprout after burns, but may be reduced in stature post

burn, thus less competitive towards regenerating tree seedlings (Elliot *et al.* 1999). *Kalmia latifolia* leaves are highly flammable due to their high oil content (League 2005). This oil content is greatest during the growing season, thus growing season burns could reduce *K. latifolia* (League 2005). *Kalmia latifolia* has been found to decrease (Elliot *et al.* 1999) and increase (Ducey *et al.* 1996) post early growing season burns. Dormant burns have been shown to increase *Kalmia latifolia* seedlings (Arthur *et al.* 1998). The lack of oil content in the leaves could potentially be allowing *K. latifolia* to thrive post early growing season and dormant season burns. *Kalmia latifolia* can also reduce the growth and reproduction of tree seedlings and other woody vegetation, such as *G. brachycera*, *G. baccata*, and *Vaccinium* species.

In summary, to minimize the impact to *Quercus* spp. in the canopy dormant season burns should be prescribed. However, to reduce competing canopy species in the understory, such as *A. rubrum* and *N. sylvatica*, increase *Quercus* seedlings and saplings, and increase, *G. brachycera*, *G. baccata*, and *Vaccinium* species growing season burns should be implemented according to the literature.

We conducted a vegetation survey to determine if there was a significant difference between dormant and growing season burns compared to a no burn-control with regard to woody vegetation abundance. We hypothesized that prescribed burns would have differing effects on woody vegetation, depending on fire and shade tolerance. We predicted that *Quercus* seedlings and saplings and understory shrub species, *G. brachycera*, *G. baccata*, and *Vaccinium* spp. would increase after a growing season burn due to the decrease in competition from shade and fire-intolerant species. We predicted oak competitor, *A. rubrum*, would decrease post growing season burn as well (Brose

2010; Brose & Van Lear 1998; Elliot *et al.* 1999). We also predicted repeated burns would result in greater abundance of regeneration of *Quercus* spp. (Arthur *et al.* 1998; Dey & Hartman 2005; Fan *et al.* 2012) and a decrease in competitive species, *N. sylvatica* (Arthur *et al.* 1998; Dey & Hartman 2005; Fan *et al.* 2012).

## METHODS

### *Study Site*

The field study was conducted June through July 2014 on Buck Mountain in Hardy County, West Virginia. Buck Mountain is located in the Lee Ranger District of the George Washington National Forest (GWNF). Under the 1993 Revised Forest Land and Resource Management Plan for the GWNF, the USFS designates Buck Mountain a Management Area 4 (Special Interest Area-Biologic), also known as a Special Biological Area (Huber 2007). Special Interest Areas-Biologic (SIA-Biologic) are areas that support key components and concentrations of the GWNF's biodiversity (USDA 1993).

Xeric pine-oak forests are present on Buck Mountain. Overstory composition was dominated by *Nyssa sylvatica*, *Pinus* spp. (mainly *Pinus rigida*), and *Quercus prinus*. The midstory was primarily composed of *Quercus ilicifolia*, *Hamamelis virginiana* and *Sassafras albidum*. In the understory, mainly *Vaccinium* spp., *Gaylussacia brachycera*, *Gaylussacia baccata*, *Gaultheria procumbens* and *Kalmia latifolia* were present.

Buck Mountain consists of seven burn blocks (Figure 1). The USFS prescribes burns within these burn blocks. We used three of the seven burn blocks, and created a control treatment for this study. The area of the control treatment was created based on the property lines of the GWNF. Specifically, we sampled vegetation from burn blocks I,

III, and VI. Burn block I consisted of two burns. The first burn was prescribed in the dormant season of 1987, and the second burn was prescribed, 24 years later, in the growing season of 2011. Burn block III also had two prescribed burns. The first burn was prescribed in the dormant season of 1998, and a second burn was conducted 13 years later, in the dormant season of 2011. In 1996, burn block VI had one dormant season burn prescribed. A control treatment was created adjacent to burn block I; the area had no history of burns.

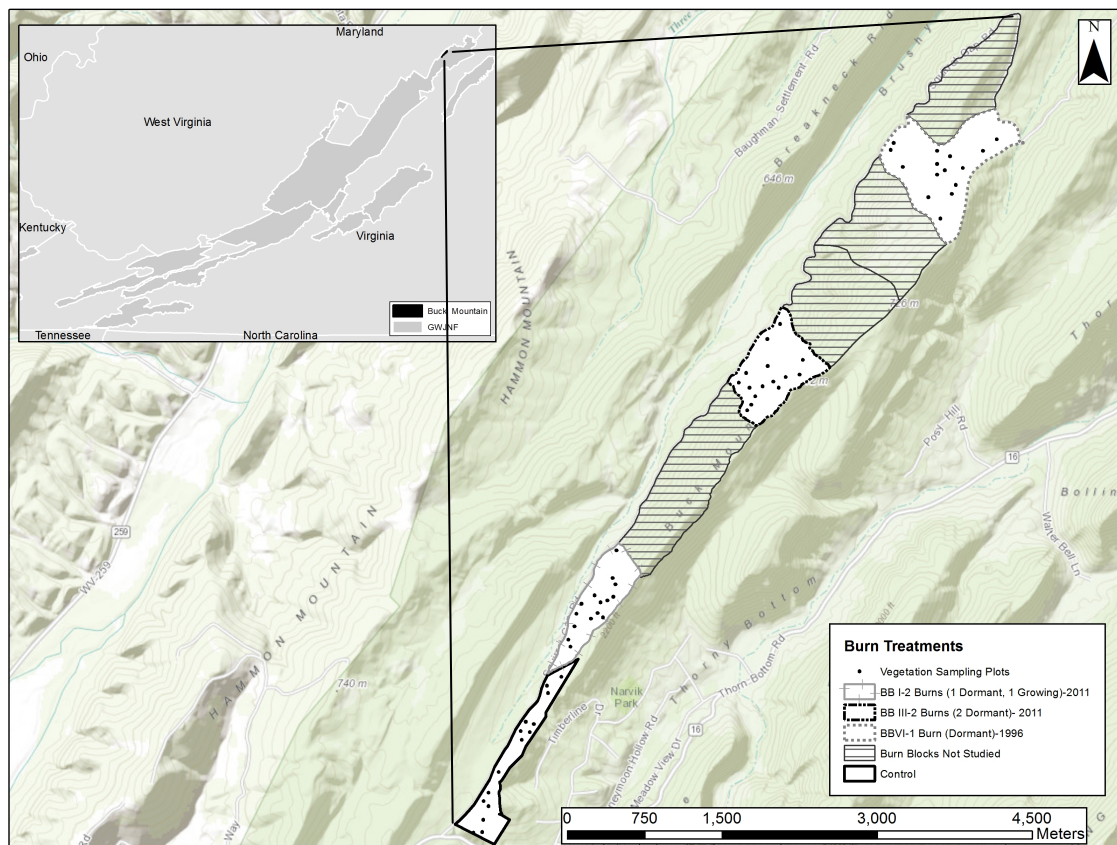


Figure 1. Map of study site with burn treatments and vegetation sampling plots on Buck Mountain, West Virginia. Buck Mountain is located in the George Washington National Forest.

Fifteen plots were randomly placed within each burn block using the Create Random Points tool in ArcGIS. Plots were 40 m in diameter (area= 1257 m<sup>2</sup>) and at least



50 m apart. Plots ranged from 566 m to 691 m in elevation. A majority of the plots had a northwest-facing aspect, ranging in slope from 2° to 32°. In the field, plots were located with a Trimble GPS unit using waypoints. Plot centers had to be at least 30 m from the edge of each burn treatment. Eight plots had to be moved in the field due to close proximity to the edge of the treatment or hazardous field conditions.

### *Vegetation Sampling*

Using a nested subplot design we counted adult trees, tree saplings, tree seedlings, and shrub species. We measured and identified all trees within the 1257 m<sup>2</sup> area of the plot (1/8<sup>th</sup> ha plot). An individual qualified as an adult tree if the DBH was greater than or equal to 5 cm. Snags (dead, standing tree) were also counted and measured in the 1257 m<sup>2</sup> area. Tree saplings were identified within the 625 m<sup>2</sup> area of the subplot (1/16<sup>th</sup> ha plot). An individual was considered a sapling if they were greater than 1 m in height, and had a DBH less than 5 cm. Tree seedlings were identified within the 125 m<sup>2</sup> area of the subplot (1/80<sup>th</sup> ha plot). Seedlings were less than 1 m in height. Individual shrub stems were identified and counted within the 3 m<sup>2</sup> area of the subplot. A shrub was defined as a short, woody plant with several branching stems.

### *Data Analysis*

Species abundances for adult trees, tree saplings, tree seedlings, and shrubs were calculated from the vegetation sampling. Total density (# individuals/ ha) was then calculated for selected species of adult trees, tree saplings, tree seedlings, and shrubs. Using DBH measurements of selected adult tree species basal area per ha (m<sup>2</sup>) was also

calculated. To analyze total density (# individuals/ ha) and basal area per ha ( $\text{m}^2$ ) of adult tree species ANOVA or Kruskal-Wallis tests were used (IBM SPSS Statistics 22).

Kruskal-Wallis was used when data were not normal. If Kruskal-Wallis revealed significant differences between the four treatments post-hoc tests were performed. Groups were selected based on treatment and other Kruskal-Wallis tests were performed as a post hoc. However, if data were normal ANOVA analyses was performed. If ANOVA analyses showed significant differences between the treatments, a post hoc Tukey test was performed. Importance values (IV) for selected adult tree species were also calculated using the equation:  $(\text{relative density} + \text{relative basal area}) / 2$ .

## RESULTS

### *Effect of fire on the canopy*

*Nyssa sylvatica*, *Quercus prinus*, and *Pinus* spp. (*P. rigida*, *P. virginiana*, and *P. strobus*) were the trees in the canopy with the greatest importance values on Buck Mountain (Table 1). *Quercus* spp. (mainly *Q. prinus*) maintained co-dominance with *Pinus* spp. in the canopy only at the site that had been burned once (IV= 0.32, basal area per ha= 7.94) (in 1996), 18 years before this survey (Table 1, Figure 2).

Oak competitor, *N. sylvatica*, either dominated or co-dominated the canopy at the no-burn, control site (IV= 0.50, basal area per ha= 7.57) and the sites that been burned twice during the dormant season (IV= 0.84, basal area per ha= 2.85) or burned twice during a dormant and growing season (IV= 0.30, basal area per ha= 3.45) (Table 1, Figure 2).

The two burn site (dormant burn followed by growing burn) had a total basal area of 10.45 per ha ( $\text{m}^2$ ), the lowest total basal area of all the burn sites compared to the control which had the greatest basal area of 18.01 per ha ( $\text{m}^2$ ) (Table 2). *Acer rubrum* was infrequently found at all sites in the canopy.

Table 1. Importance values (IV) and standard deviations ( $\pm$  SD) for six most prevalent adult tree species in the no-burn and burn treatments. Numbers in parentheses rank species of importance. Numbers bolded are the dominating tree species in the canopy at each site. Importance values were calculated using the equation: (relative density + relative basal area)/ 2. C= no-burn, DG= 1 dormant burn followed by growing season burn, DD= dormant burn followed by dormant burn, D= 1 dormant burn.

	<b>Control (C)</b>		<b>2 Burns (DG) 2011</b>		<b>2 Burns (DD) 2011</b>		<b>1 Burn (D) 1996</b>	
<b>Species</b>	<b>IV</b>	<b>SD</b>	<b>IV</b>	<b>SD</b>	<b>IV</b>	<b>SD</b>	<b>IV</b>	<b>SD</b>
<i>A. rubrum</i>	0.02 (6)	$\pm$ 0.01	0.02 (5)	$\pm$ 0.04	0.02 (5)	$\pm$ 0.03	0.01 (6)	$\pm$ 0.02
<i>N. sylvatica</i>	<b>0.50 (1)</b>	$\pm$ 0.08	<b>0.30 (2)</b>	$\pm$ 0.17	<b>0.84 (1)</b>	$\pm$ 2.43	0.24 (3)	$\pm$ 0.08
<i>Q. prinus</i>	0.19 (2)	$\pm$ 0.11	0.10 (4)	$\pm$ 0.08	0.33 (2)	$\pm$ 0.22	<b>0.32 (1)</b>	$\pm$ 0.20
Snag	0.05 (5)	$\pm$ 0.02	0.27 (3)	$\pm$ 0.16	0.11 (4)	$\pm$ 0.08	0.06 (4)	$\pm$ 0.03
<i>Pinus</i> spp.	0.13 (3)	$\pm$ 0.09	<b>0.30 (1)</b>	$\pm$ 0.15	0.31 (3)	$\pm$ 0.27	<b>0.29 (2)</b>	$\pm$ 0.23
<i>Quercus</i> spp.	0.09 (4)	$\pm$ 0.07	0.01 (6)	$\pm$ 0.03	0.01 (6)	$\pm$ 0.03	0.05 (5)	$\pm$ 0.04

Table 2. Total density (# individuals/ ha) and total basal area per ha ( $\text{m}^2$ ) for selected adult tree species of the burn treatments (n=60). C= no-burn, DG= 1 dormant burn followed by growing season burn, DD= dormant burn followed by dormant burn, D= 1 dormant burn.

Treatments	Total Density (# individuals/ ha)	Total Basal Area per ha ( $\text{m}^2$ )
Control (C)	825	18.01
2 Burns (DG)-2011	589	10.45
2 Burns (DD)-2011	442	14.29
1 Burn (D)-1996	486	12.84

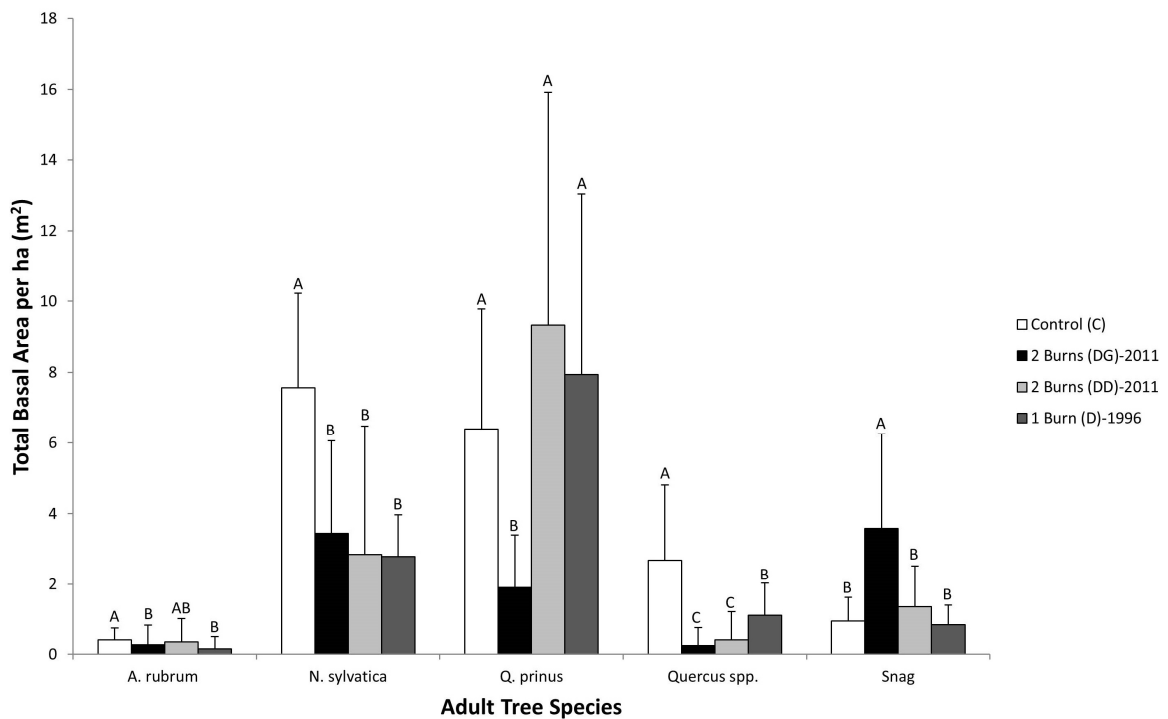


Figure 2. Total basal area per ha ( $\text{m}^2$ ) for selected adult tree species (n=60). Selection was based off of importance and dominance in the canopy. Different letters indicate significant difference between burn treatments (ANOVA; Kruskal Wallis;  $p \leq 0.05$ ; + SD). C= no-burn, DG= 1 dormant burn followed by growing season burn, DD= dormant burn followed by dormant burn, D= 1 dormant burn.

### *Effect of fire on the understory*

The effect of burning on tree regeneration in the understory varied depending on species and age (sapling or seedling). Few saplings were found at any of the sites. On

average, there were only 117 saplings/ ha at each site. In the sapling cohort, only *N. sylvatica* was negatively and significantly affected by fire ( $p \leq 0.05$ ) (Figure 3).

Conversely, *Q. ilicifolia* saplings were most abundant where fire had been prescribed, but not significantly (Figure 3).

Seedlings were much more abundant, with the most seedlings found in the control (1396 individuals/ ha). *Acer rubrum* seedlings, although rare in the canopy and sapling layer, dominated seedlings in the control plots (907 individuals/ha) and were significantly more abundant than at the burn sites ( $p \leq 0.05$ ) (Figure 4). On the other hand, at the site that had been burned 18 years ago, *Q. prinus* was the most common seedling (Figure 4). At the site burned twice, with the most recent burn occurring in 2011 (3 years before this survey), *Q. ilicifolia* and *N. sylvatica* dominated the seedling layer (Figure 4). Interestingly, a slightly different pattern emerged at the other site that had been burned twice. Here, *Q. ilicifolia* still dominated the seedling layer, but not *N. sylvatica* (Figure 4).

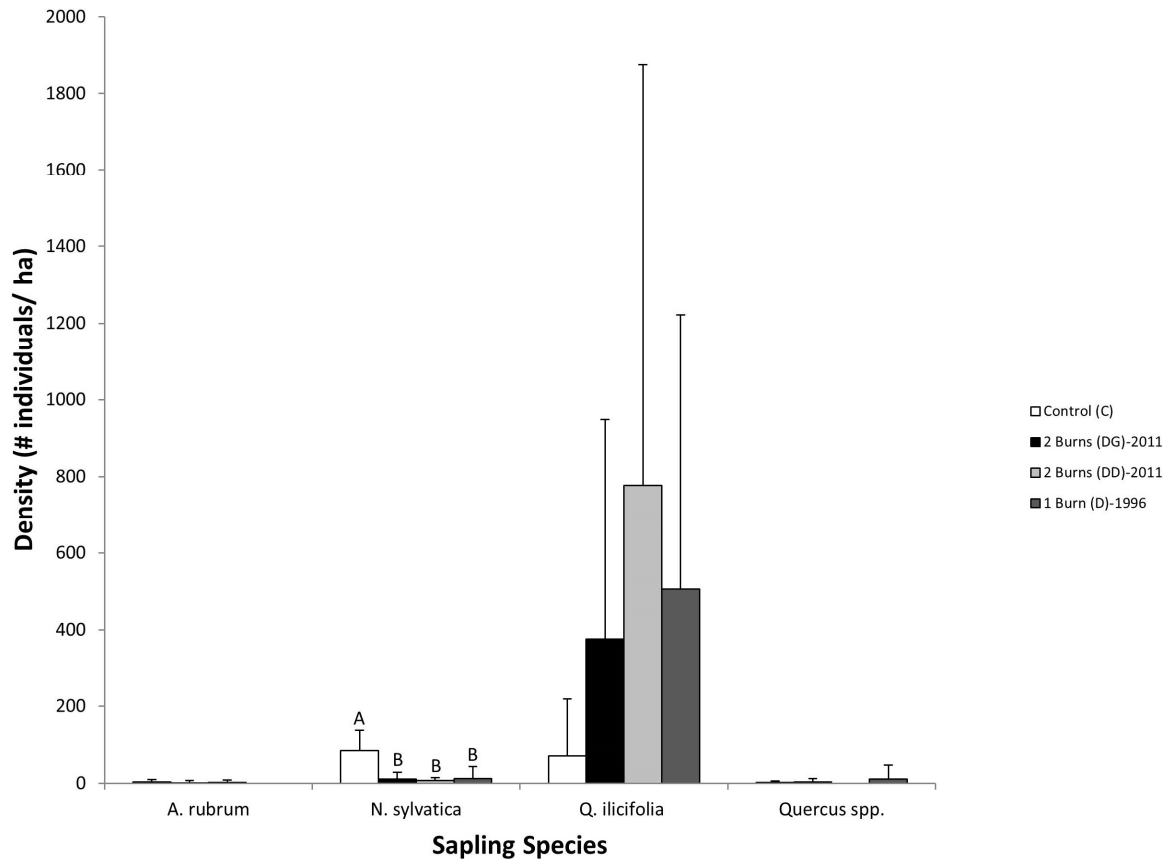


Figure 3. Density (# individuals/ ha) for selected tree sapling species (n=60). Selection was based off of importance and dominance in the understory. Different letters indicate significant difference between burn treatments (Kruskal Wallis;  $p \leq 0.05$ ; + SD). C= no-burn, DG= 1 dormant burn followed by growing season burn, DD= dormant burn followed by dormant burn, D= 1 dormant burn.

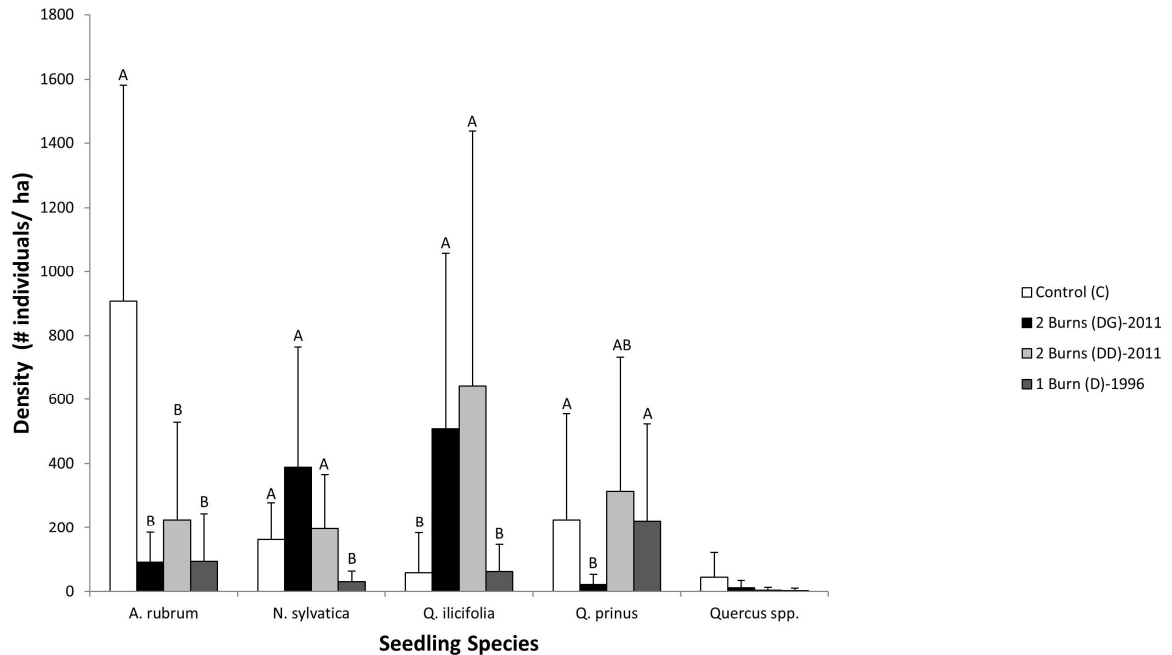


Figure 4. Density (# individuals/ ha) for selected tree seedling species (n=60). Selection was based off of importance and dominance at the seedling layer. Different letters indicate significant difference between burn treatments (Kruskal Wallis;  $p \leq 0.05$ ; + SD). C= no-burn, DG= 1 dormant burn followed by growing season burn, DD= dormant burn followed by dormant burn, D= 1 dormant burn.

#### *Effect of fire on shrub species*

All species in the Ericaceae (*K. latifolia*, *Vaccinium* spp., and *G. brachycera*) increased with fire, except for *Gaultheria procumbens* (winterberry). Oak competitor, *K. latifolia* was most abundant after two burns and least abundant in the control (Figure 5). Desired shrubs, such as *Vaccinium* spp. were most abundant at the 1996 burn site (18 years since a burn occurred) (Figure 5). *Vaccinium* spp. were least abundant at the control site with 166 individual stems/ ha (Figure 5). Interestingly, *G. procumbens* was the most abundant shrub species in the control with 477 individuals/ ha (Figure 5). Another desired shrub species, *G. baccata* was most abundant post two burns and least abundant at the 1996 burn site (Figure 5).



Endangered shrub, *G. brachycera* was also positively affected by burning.

However, no significant differences were found due to the nature of the plant.

*Gaylussacia brachycera* was found in large patches, consisting of clones, or none at all.

However, the pattern that emerged was that *G. brachycera* proliferated at the burn sites.

Densities of *G. brachycera* ranged from 395 to 724 (# individual stems/ ha) at the burn sites compared to just 135 (# individual stems/ ha) at the control (Figure 5).

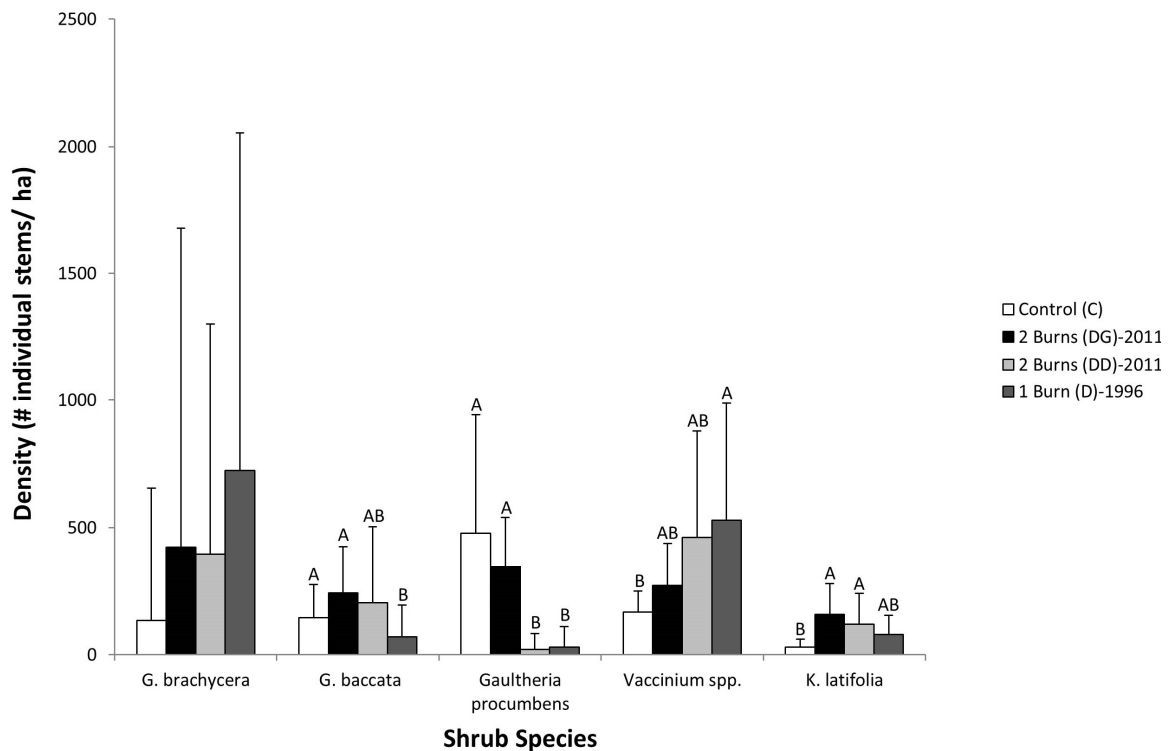


Figure 5. Density (# individual stems/ ha) for selected shrub species (n=60). Selection was based off of importance and dominance in the shrub layer. Different letters indicate significant difference between burn treatments (Kruskal Wallis;  $\leq 0.05$ ; + SD). C= no-burn, DG= 1 dormant burn followed by growing season burn, DD= dormant burn followed by dormant burn, D= 1 dormant burn.

## DISCUSSION

### *Summary*

Prescribed burns had differing effects on woody vegetation at Buck Mountain, depending on the fire and shade tolerance of the species. *Quercus prinus*, *N. sylvatica*, and *Pinus spp.* were the more dominant canopy or sub canopy species at the burn sites compared to the control where *N. sylvatica* dominated (Table 1). *Acer rubrum*, a common competitor of oak, was not common in either the canopy or subcanopy and consequently, there was not an abundant source of seeds. Surprisingly, few saplings of any species were found on the mountain. Deer herbivory may have decreased sapling densities. After a burn, woody vegetation produces new shoots that are more palatable, thus attracting deer to newly burned sites (Hallisey & Wood 1976). On the other hand, seedlings were abundant, especially in the control with *A. rubrum* dominating. However, at the repeated burn sites *N. sylvatica*, *Q. ilicifolia*, and *Q. prinus* seedlings dominated the understory.

On Buck Mountain, desired species (*Quercus* seedlings, *G. brachycera*, *G. baccata* and *Vaccinium spp.*) benefited from burning, regardless of season. In general, regeneration of undesired species (*A. rubrum* and *N. sylvatica*) was reduced, except for *K. latifolia*.

### *Oak regeneration*

An increase in oak regeneration is a management goal of the USFS because mast producing species are a food source for wildlife. In addition, *Q. ilicifolia* communities are decreasing in the eastern U.S., thus are a species of special concern (Gucker 2006).

We predicted oak regeneration would benefit the greatest from a growing season burn (Brose 2010; Brose & Van Lear 1998; Brose *et al.* 1999; Elliot *et al.* 1999). This is because oak competitors, such as *A. rubrum*, are also greatly reduced (Brose 2010; Brose & Van Lear 1998; Elliot *et al.* 1999). However, in this study, seasonality of those burns was irrelevant to *Q. ilicifolia* (the most common *Quercus* spp.) seedling density. Frequency of burns was more important with the greatest abundance of *Q. ilicifolia* at the site burned twice. Hallisey and Wood (1976) also found that *Q. ilicifolia* was the product of periodic fires. Other *Quercus* spp. have been found to benefit from repeated burns (Fan *et al.* 2012; Dey & Hartman 2005). Arthur *et al.* (1998) found *Q. prinus* seedlings benefited greatly from two burns. Thus, repeated prescribed burns are needed to promote the regeneration of *Q. ilicifolia* and other *Quercus* species.

#### *Oak competitors*

In the southeastern U.S., shade tolerant species, such as *A. rubrum* and *N. sylvatica*, have been dominating canopies with lack of fire. To reduce *A. rubrum* regeneration we predicted a growing season burn was best, as during the growing season *A. rubrum* are more physiologically active, thus burning can hinder growth (Green *et al.* 2010). Also, various studies have found growing season burns to negatively affect *A. rubrum* regeneration (Elliot *et al.* 1999; Brose 2010; Brose & Van Lear 1998). However, although seedlings were numerous, few *A. rubrum* saplings were found at any site; on average there were only 2 individuals/ ha on Buck Mountain (Figure 3). Perhaps, at this less productive site with more light reaching the understory, *A. rubrum* seedlings are being outcompeted, thus are not reaching the sapling stage. Due to higher light levels,

more light demanding species, such as *Q. ilicifolia* out-compete *A. rubrum* at the sapling stage. Fire, in general, significantly reduced *A. rubrum* seedlings, but seasonality of the burn was not important (Figure 4).

Contrary to *A. rubrum*, we predicted that seasonality would not affect *N. sylvatica*, but repeated burns would decrease regeneration (Arthur *et al.* 1998; Dey & Hartman 2005; Fan *et al.* 2012). Fire (both dormant and growing season) reduced *N. sylvatica*. *Nyssa sylvatica* seedling density was lowest at the single dormant season burn treatment (1996 burn) with 31 individuals/ ha (Figure 4). This is most likely a combination of a negative effect of fire as well as time since the last burn. The seedling density at the single dormant burn was significantly lower than the control, showing fire did have an effect on reducing the oak competitor (Figure 4). However, since the site was burned 18 years ago, perhaps time could have also influenced the reduction of the species, by allowing other tree species to outcompete *N. sylvatica*.

#### *Desired shrub species*

To increase desired shrub species, such as *G. brachycera*, *G. baccata*, and *Vaccinium* species we predicted a growing season burn was best for regeneration since Elliot *et al.* (1999) found an increase in species in Ericaceae. Also, Arthur *et al.* (1998) found dormant burns had negatively affected desired species in Ericaceae. However, we found no positive effect of fire. *Gaylussacia brachycera*, a threatened species, showed high variability between plots. Burning increased *G. brachycera*, but not significantly (Figure 5). *Gaultheria procumbens*, the only shrub species significantly reduced by

burning, is a fire sensitive (Coladonato 1994). Thus, the low densities of *G. procumbens* at the burn sites are reasonable.

#### *Future studies and management*

The U.S. Forest Service should continue to burn on Buck Mountain to promote oak and *G. brachycera* regeneration. Our results suggest that seasonality of burns did not affect oak and *G. brachycera* regeneration at Buck Mountain. Dormant season burns are not detrimental to oak or *G. brachycera* regeneration, even though the natural fire regime of the area is in the growing season. Also, if dormant season burns protect nesting game birds, and are easier to implement then the USFS should continue their practice of dormant season burning in locations floristically similar to Buck Mountain.

Future vegetation monitoring is needed to determine if time intervals between burns effects regeneration of desired species rather than the season of burn. Sampling at different time intervals between burns can determine the ideal burning time for maximum regeneration of *Quercus* and desired shrub species. Due to the lack of studies and scarcity of *G. brachycera* populations, the U.S. Forest Service should continue to monitor *G. brachycera* patches on Buck Mountain. Long term studies are needed to determine the seasonality of burns on oak and *G. brachycera* regeneration. Regeneration of woody species takes years, thus long term studies are needed to monitor regeneration.

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